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ART VI.—*Symptoms of Copper Deficiency in Flax.*

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Abstract.

Wheat and flax plants in copper deficient water cultures developed severe symptoms of malnutrition. The wheat symptoms were identical with those of "reclamation disease." The flax plants showed a general chlorosis, and a somewhat rosetted appearance of the top of the plant due to shortening of the internodes. The leaves became puckered, slightly inrolled along the edges, and very twisted. Growth finally ceased, and the plants commenced to die from the top.

Introduction.

Owing to the difficulty experienced by early workers in removing small traces of copper from their nutrient solutions, the essential nature of this element for plant growth was not demonstrated until comparatively recently. Sommer (1931) was the first to show that the absence of copper in the nutrient solution resulted in a very appreciable reduction in the growth of flax, sunflowers and tomatoes; but she did not describe the symptoms manifested by the copper deficient plants.

More recently other workers, notably Brandenburg (1935), van Schreven (1936) Arnd and Hoffmann (1937), Stout and Arnon (1939) and Piper (1940, 1942) have confirmed the findings of Sommer and have described the symptoms of copper deficiency in a wide variety of plants. However, before the most recent paper of Piper, there had apparently been no description of copper deficiency symptoms in flax. In view of this in 1941 and 1942, Free Gallipoli wheat plants and Liral Crown flax plants were grown in copper deficient water cultures at the Plant Research Laboratory, Burnley, primarily with the object of determining the symptoms of copper deficiency in flax. Wheat was included in the experiment, as the symptoms of copper deficiency in cereals were well known and, their occurrence in the cultures would afford confirmation of the degree to which the copper had been eliminated from the nutrient solution.

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Method.

The nutrient solution used was that of Arnon (1938), the composition of which was as follows:—

Potassium Phosphate ..	K_2HPO_4	.. 0.001Molar
Potassium Nitrate ..	KNO_3	.. 0.006Molar
Calcium Nitrate ..	$Ca(NO_3)_2 \cdot 4H_2O$	.. 0.004Molar
Magnesium Sulphate ..	$MgSO_4 \cdot 7H_2O$	.. 0.002Molar
Boron as Boric Acid ..	H_3BO_3	.. 0·5 parts per million
Manganese as Manganese Sulphate	$MnSO_4 \cdot 4H_2O$	.. 0·5 parts per million
Zinc as Zinc Sulphate ..	$ZnSO_4 \cdot 7H_2O$	.. 0·05 parts per million
Copper as Copper Sulphate	$CuSO_4 \cdot 5H_2O$	.. 0·02 parts per million
Vanadium as Ammonium Vanadate	NH_4VO_3	.. 0·01 parts per million
Chromium as Chrome Alum	$Cr_2K_2(SO_4)_4 \cdot 24H_2O$	.. 0·01 parts per million
Nickel as Nickel Sulphate	$NiSO_4 \cdot 6H_2O$	.. 0·01 parts per million
Cobalt as Cobalt Nitrate	$Co(NO_3)_2 \cdot 6H_2O$	.. 0·01 parts per million
Tungsten as Sodium Tungstate	$Na_2WO_4 \cdot 2H_2O$	.. 0·01 parts per million
Molybdenum as Ammonium Molybdate ..	$(NH_4)_2MoO_4$	.. 0·01 parts per million

An iron solution containing 0.5 per cent. $FeSO_4$ + 0.4 per cent. tartaric acid was added twice weekly at the rate of 0.6 ml. per litre of culture solution. When the plants were a few weeks old, this solution was added once a week. All these elements with the exception of copper were added to the copper deficient solutions. Every three-four weeks the old culture solutions were discarded and were replaced by fresh solution.

Molar stock solutions of the main constituents were purified by autoclaving with calcium carbonate in accordance with Stout and Arnon's (1939) modification of Steinberg's (1935) technique. After purification these stock solutions were tested by the dithizone test described by Stout and Arnon and found to contain less than 10 parts per billion of all metal impurities which react with dithizone. Double distilled water produced by pyrex glass stills was used to make up all solutions. The dithizone test indicated that this water contained approximately 1 part per billion of metal impurities. Stout and Arnon have shown that degrees of purity of the order of those outlined above are satisfactory for demonstrating copper deficiency symptoms in plants. All glassware was cleaned with 1 : 1 hydrochloric acid and rinsed with distilled water before use.

The plants were grown in two litre pyrex glass beakers blackened on the outside by a coat of gold size followed by two coats of black blackboard paint.

Plaster of Paris tops soaked in paraffin were used to cover the beakers and support the plants. The wheat and flax seeds were germinated in acid-washed sand, and were transferred to the beakers as soon as they could be conveniently handled. Four wheat and four flax plants were grown in the same beaker.

Results.

The following are the symptoms of copper deficiency which developed :—

WHEAT.

The first symptoms of copper deficiency appeared approximately three to four weeks after setting up the cultures. The plants were not as tall as the controls, a slight, general chlorosis became evident, and the youngest leaves were slow in unrolling The tips and distal edges of subsequently-formed leaves became markedly chlorotic and soon withered and died without unrolling (Pl. IV. fig. 1). While some secondary tillers were produced, the plants made very little further growth, with the result that no elongation or head formation occurred. The final height of the plants was approximately one foot, while the plants growing in the complete solution were over four feet high at the end of the experiment (Pl. IV. fig. 2). With the addition of small amounts of copper to wheat and oats growing in water cultures, Piper (1940, 1942) has shown that sterile heads may be produced. It was evident that the symptoms exhibited by the wheat plants growing in the copper deficient solutions were identical with those of "reclamation disease" described by other workers.

FLAX.

The flax plants grew normally for approximately four weeks, after which time growth became very retarded. The internodes between leaves produced subsequently were short, giving the top of the plant a somewhat rosetted appearance. These new leaves were much smaller than the controls and noticeably paler green in color than normal. They became puckered, slightly in-rolled along the edges, and very twisted (Pl. IV., fig. 3). The stems of the plants also showed some twisting. Later the leaves in the middle portion of the stem developed a dark, greyish-green, semi-transparent discolouration at the tips. These leaves soon drooped and withered and died from the tips downwards. The lowest leaves, on the other hand, remained apparently normal. Meanwhile, secondary shoots were sent out from the bottom, but soon became chlorotic with small twisted leaves. Finally growth ceased and the plants commenced to die from the tops.

Sommer (1931) and Piper (1942) have shown that, in the absence of copper, flax plants make very restricted growth. The symptoms of copper deficiency in flax, described by Piper, are similar to those set out above, with the exception that no twisting of the leaves was reported.

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Description of Plate.

Plate IV.

Fig. 1. Wheat leaves showing "wither tip" and inrolling characteristic of copper deficiency.

Fig. 2. Water culture experiment with wheat and flax, showing the marked reduction in growth resulting from a deficiency of copper.

Fig. 3. Copper deficiency symptoms in flax. Left: Control. Right: Copper deficient plant showing marked reduction in growth, general chlorosis, and inrolling and twisting of leaves.

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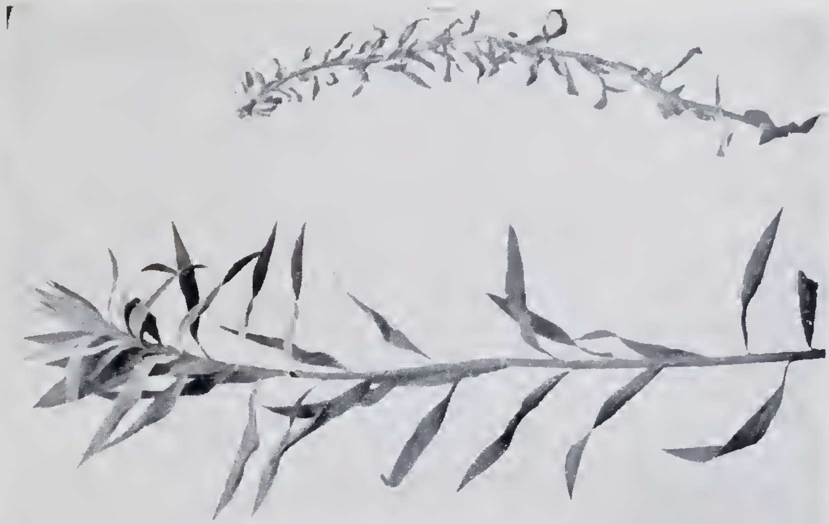

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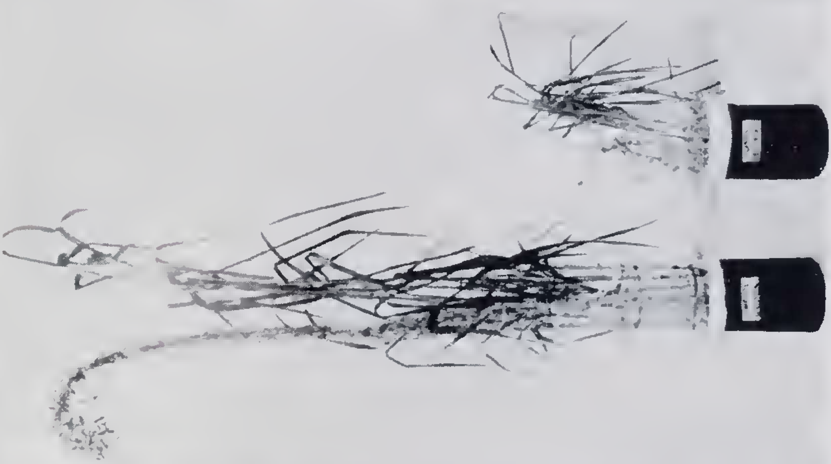

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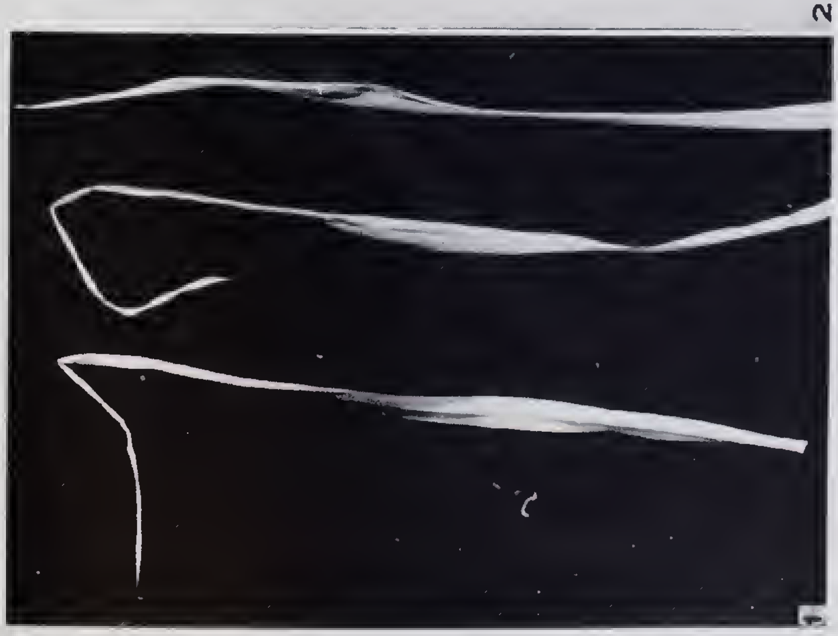

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